Controlling Beam Loss in the SNS Linac

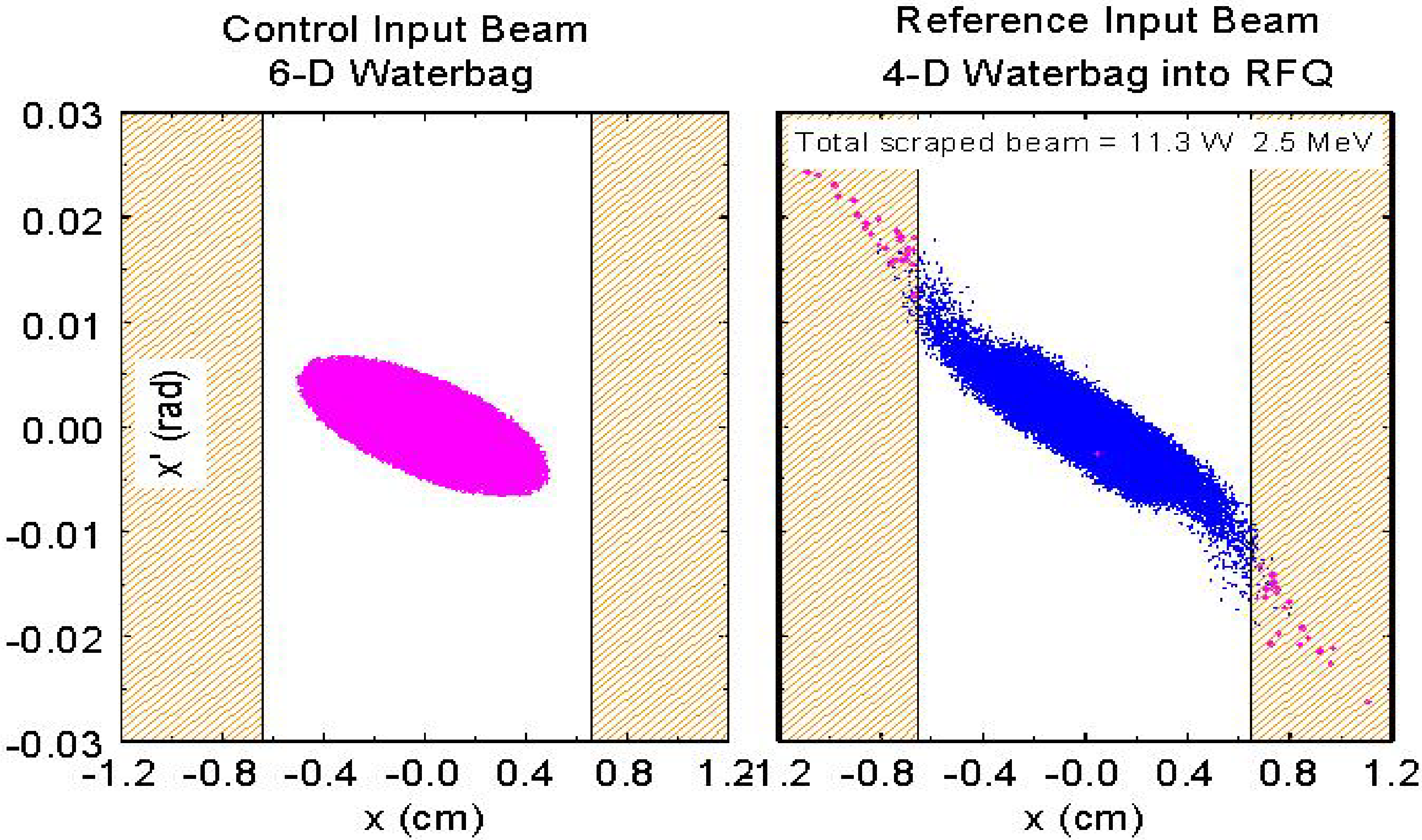
J. Stovall, D. Jeon, A. Aleksandrov, S. Kim, SNS
S. Nath, H. Takeda, L. Young, LANL
K. Crandall, TechSource Inc.

12 February 2002

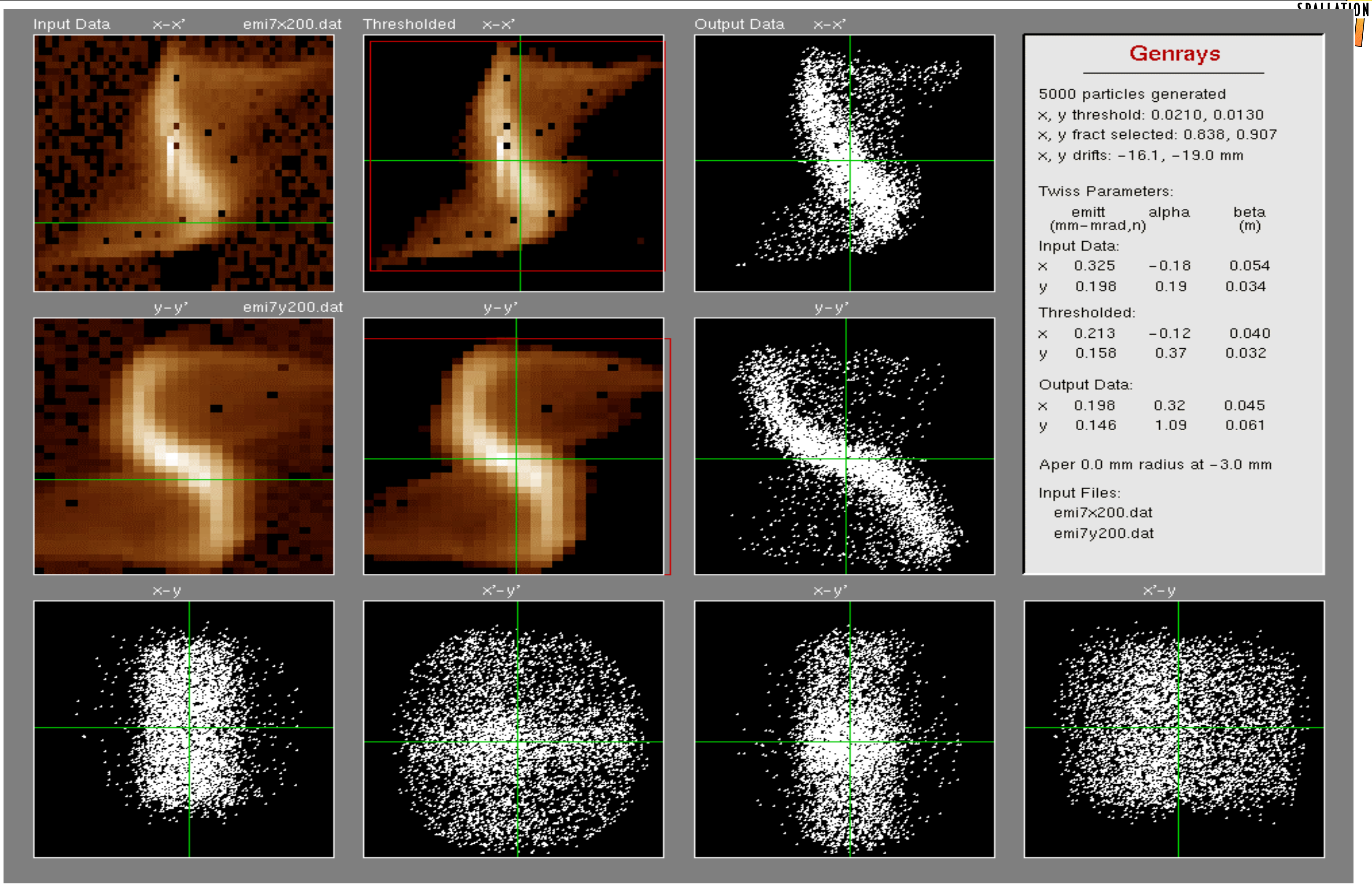
We have Identified 3 Controllable Sources of Beam Loss in the linac

- Halo formation resulting from MEBT optics
- Mismatch at the DTL entrance
- Partially chopped beams

For Design Studies we used a "Waterbag" Beam Distribution



For Beam Studies we use Distributions Constructed from Emittance Measurements



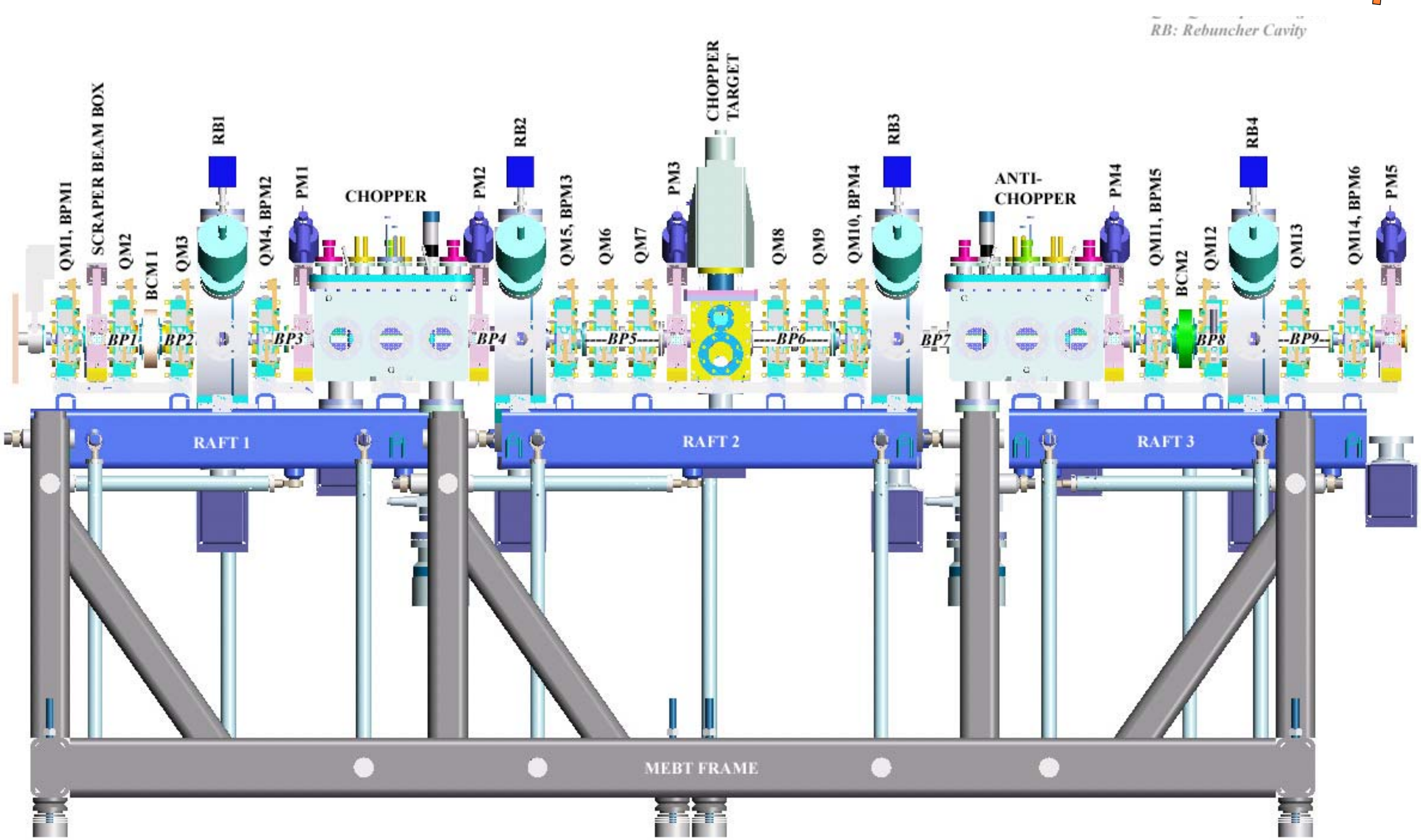
DTL Mismatches are Generated Using MEBT Tuning Algorithms

- Buncher ϕ & E_0 set-points are based on 5 BPM phase measurements
  - we assume a $\pm 1°$ error in each BPM readings
- Quadrupole gradient set-points are based on 4 wire-scanner profile measurements
  - we assume a $\pm 5\%$ error FWHM
- 10 longitudinal & transverse matches are derived for different initial conditions
  - using 10k particle input beam

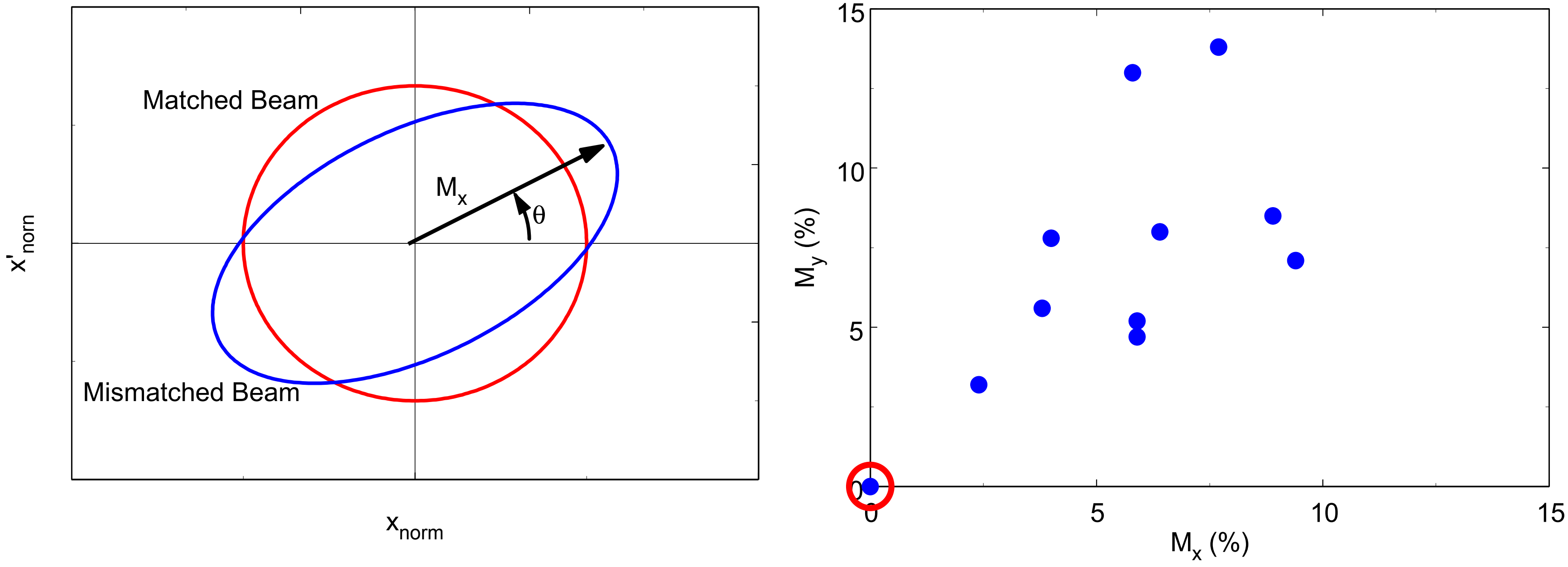
Matched Solutions with Realistic Measurement Errors Generate Mismatched Beams

- 10 solutions are defined by
  - 4 buncher phases
  - 4 buncher amplitudes
  - 10 quadrupole gradients, 7 power supplies
- 4 quads following last wire scanner can be used for “final” matching
- Study beams begin with a 300k particle “measured” distribution
- The empirically matched MEBTs produced 10 mismatched beams at the DTL

MEBT has: 4 Bunchers & 14 Quads
6 BPMs & 5 Wire Scanners

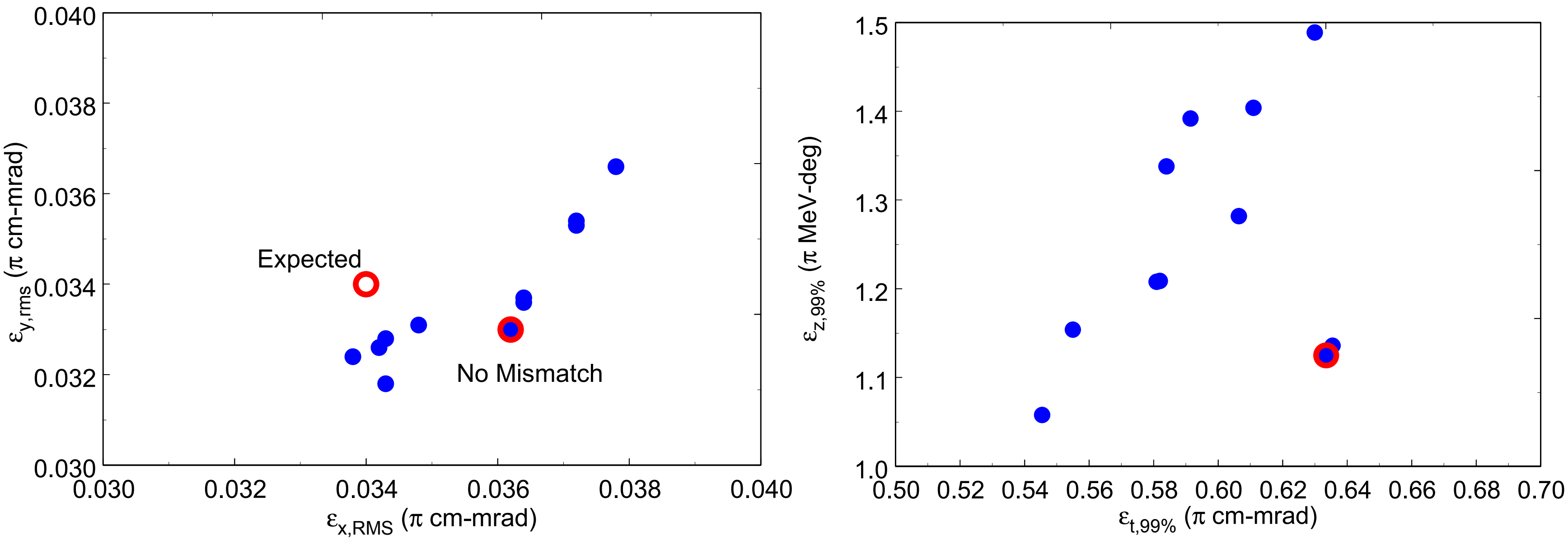


Empirical Matches with Diagnostic Errors Generate "Realistic" Mismatched Beams

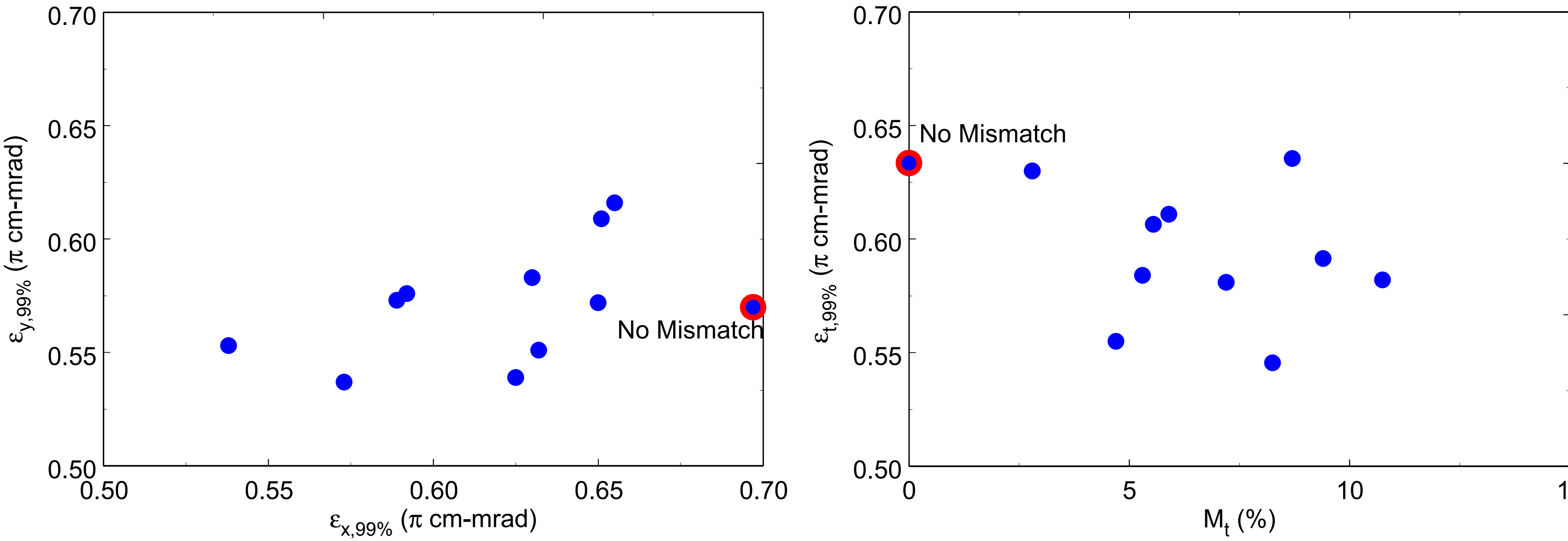


- Orientation is important but commonly omitted from mismatch studies

Energy Transfer Correlates the Emittance at the Injection Foil in all 3 Phase Planes

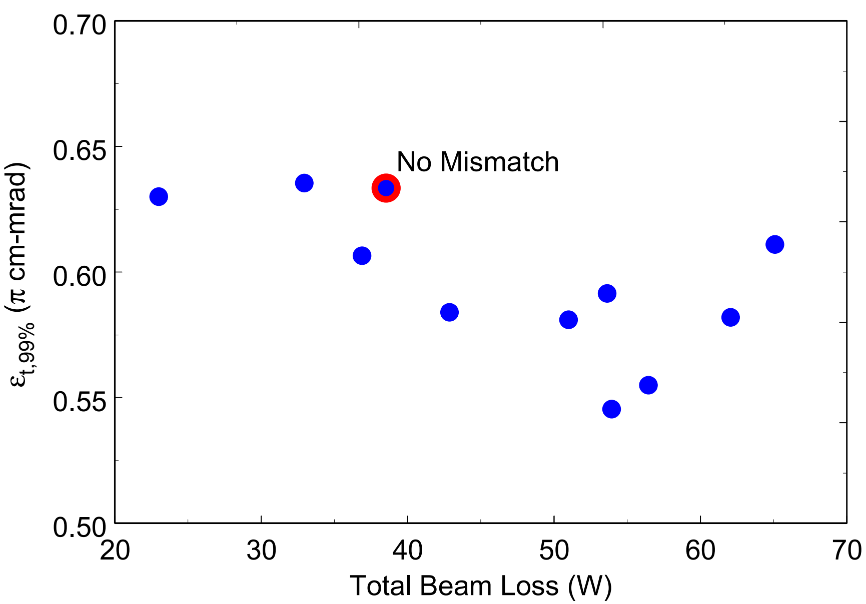


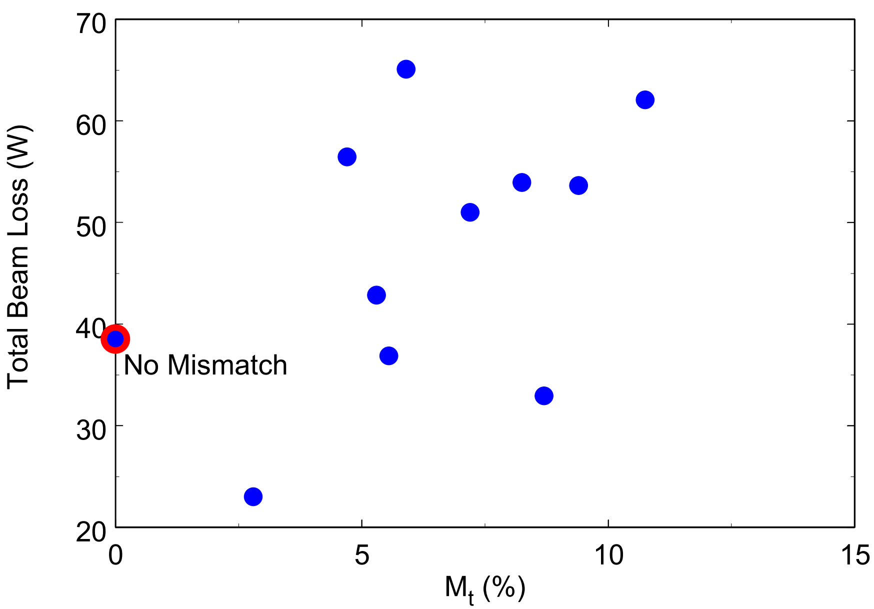
Scraping Reduces the Final Emittance of Mismatches Beams



- i.e. the linac is an effective emittance filter

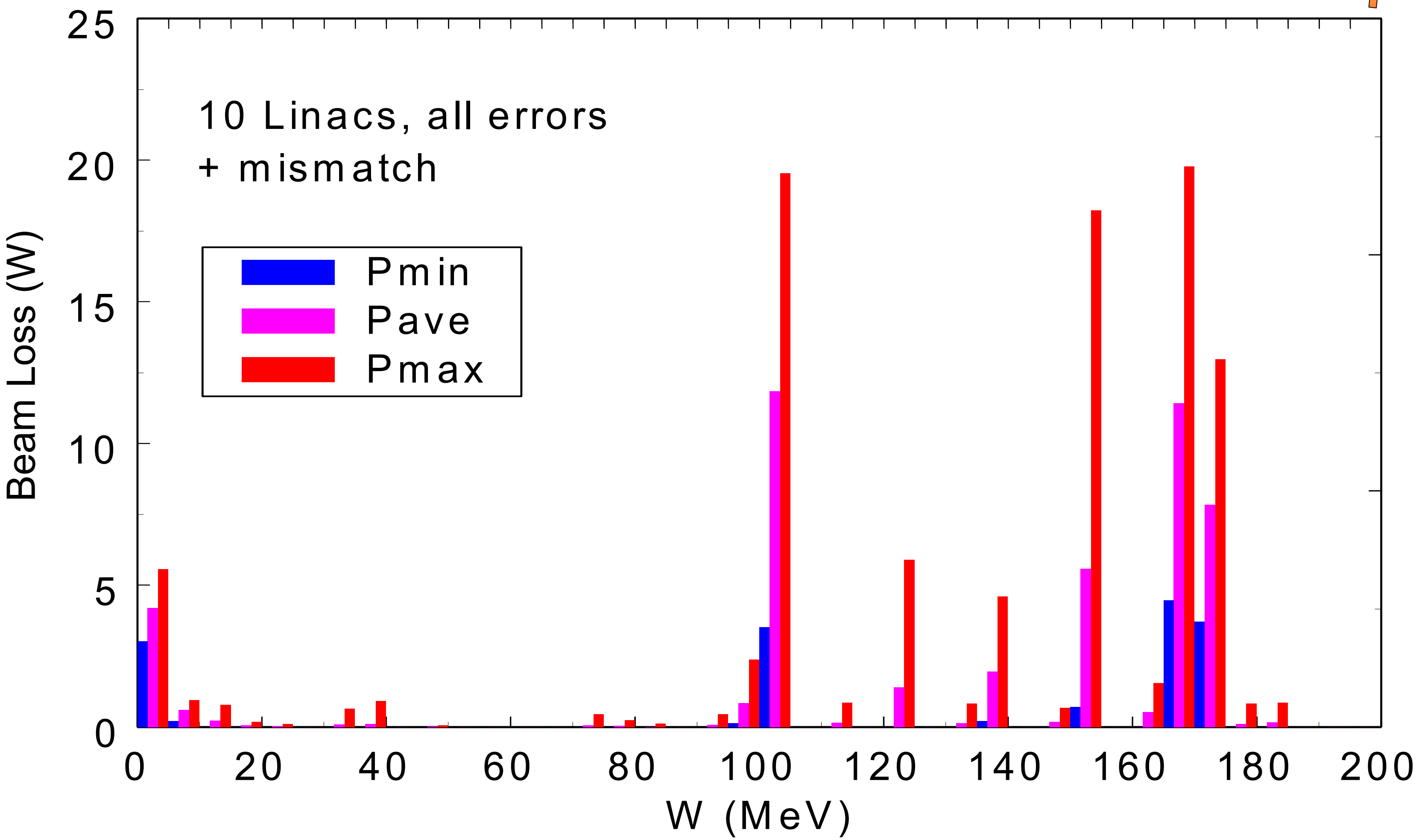
$\varepsilon_{99\%}$, Beam Loss & Mismatch are Weakly Correlated



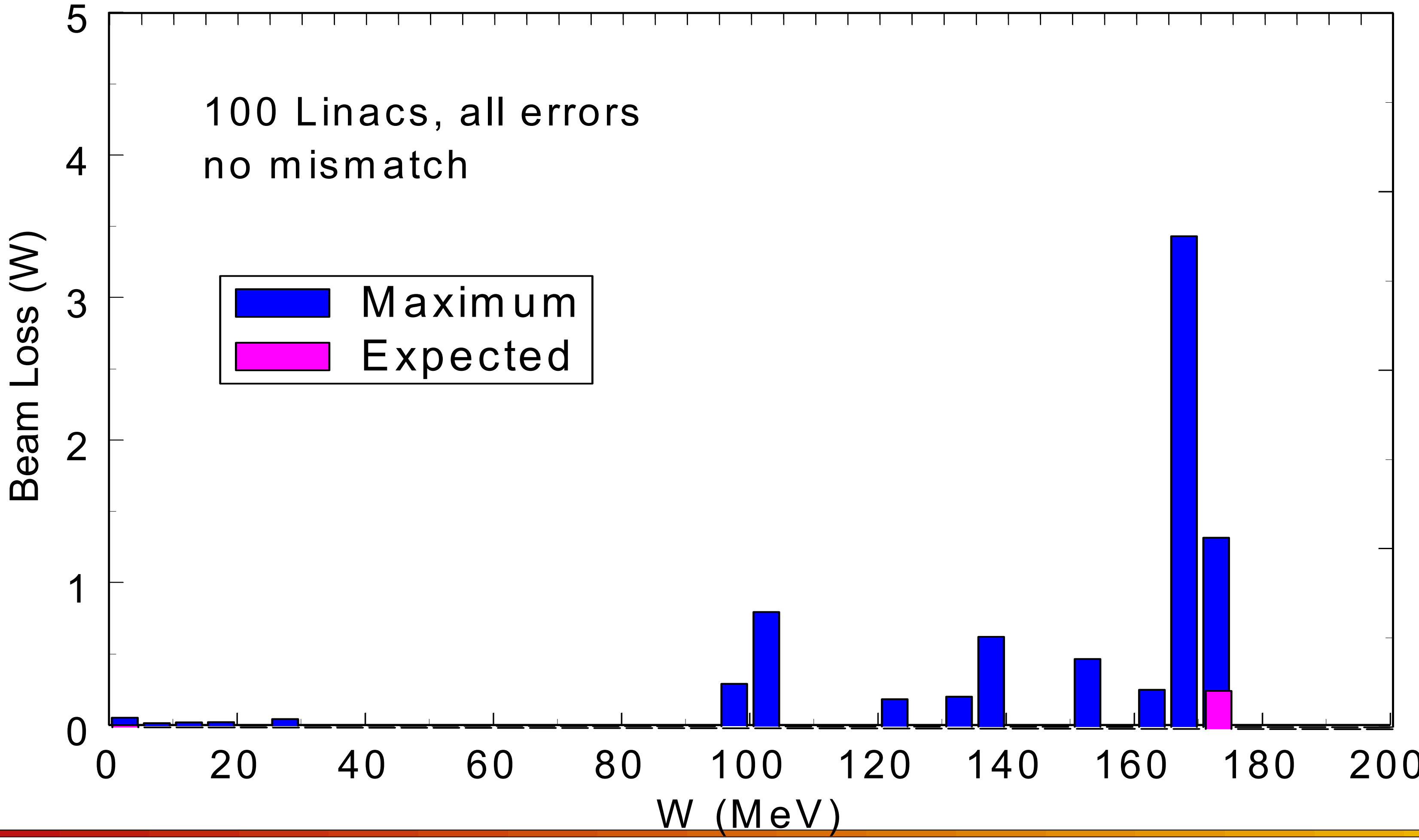


- Some beams are cleaned-up at very low energies
- Some may be better matched for the halo

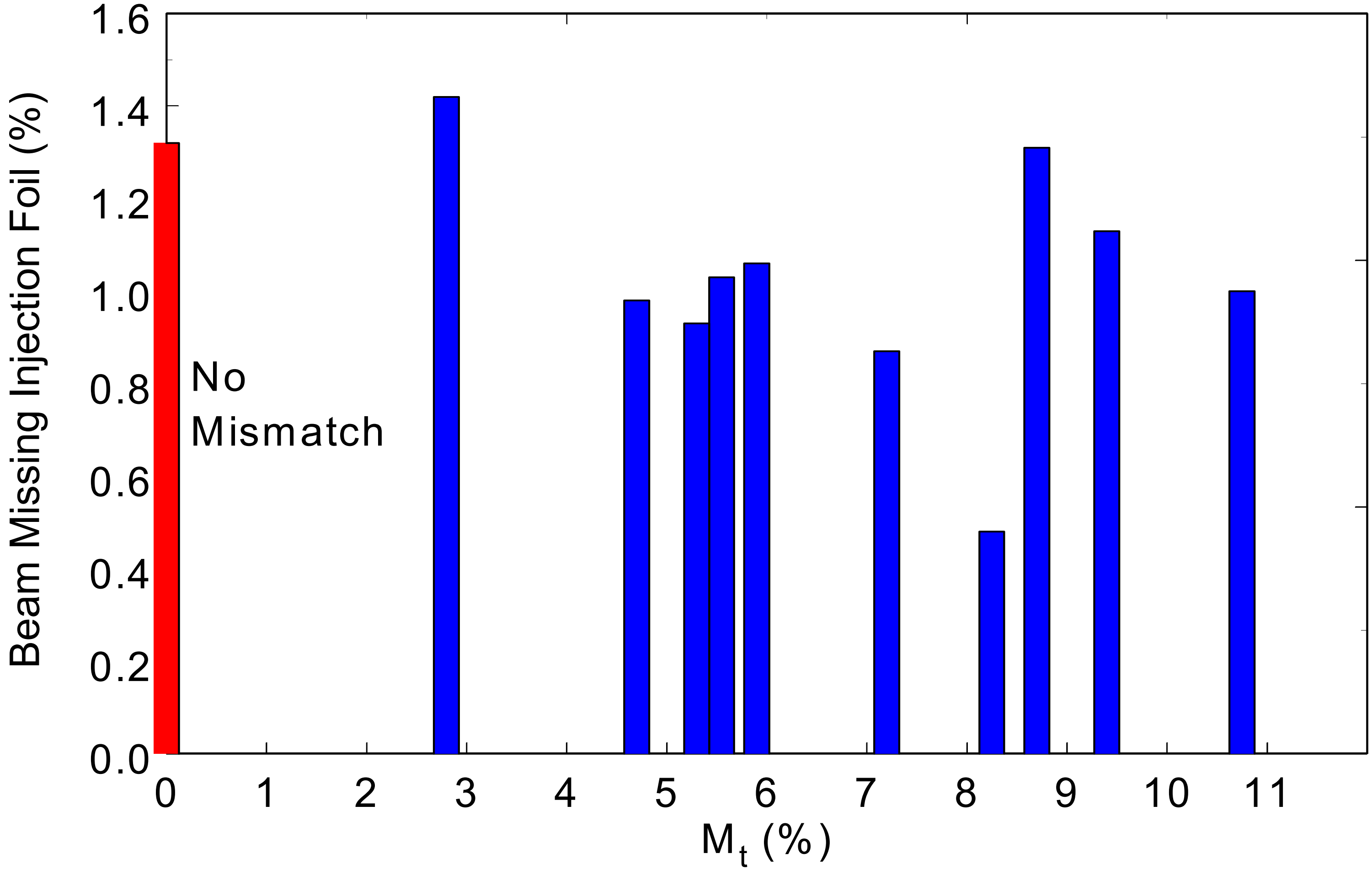
Beam Loss Occurs Primarily at Structure Interfaces for Mismatched Beams



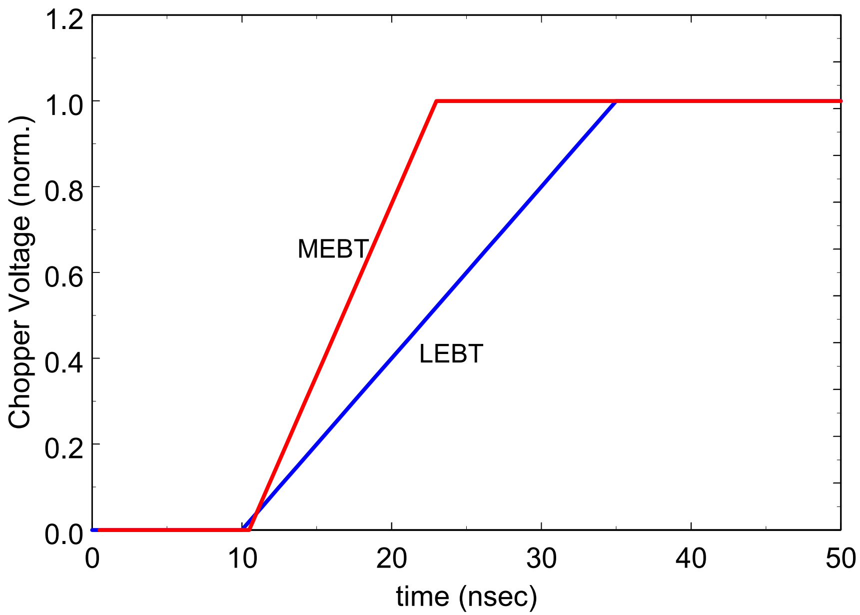
Locations of Beam Loss were Predicted by Error Studies

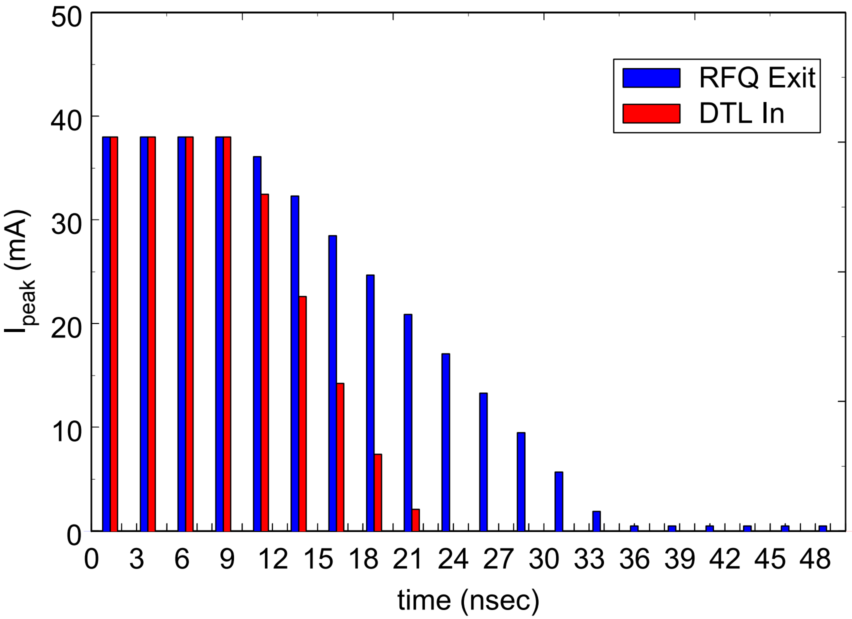


Injection Foil Misses Depends on Details of Mismatch and Scraping



Partially Chopped Bunches ≈ 1.5% of Total Beam Current or 22 kW





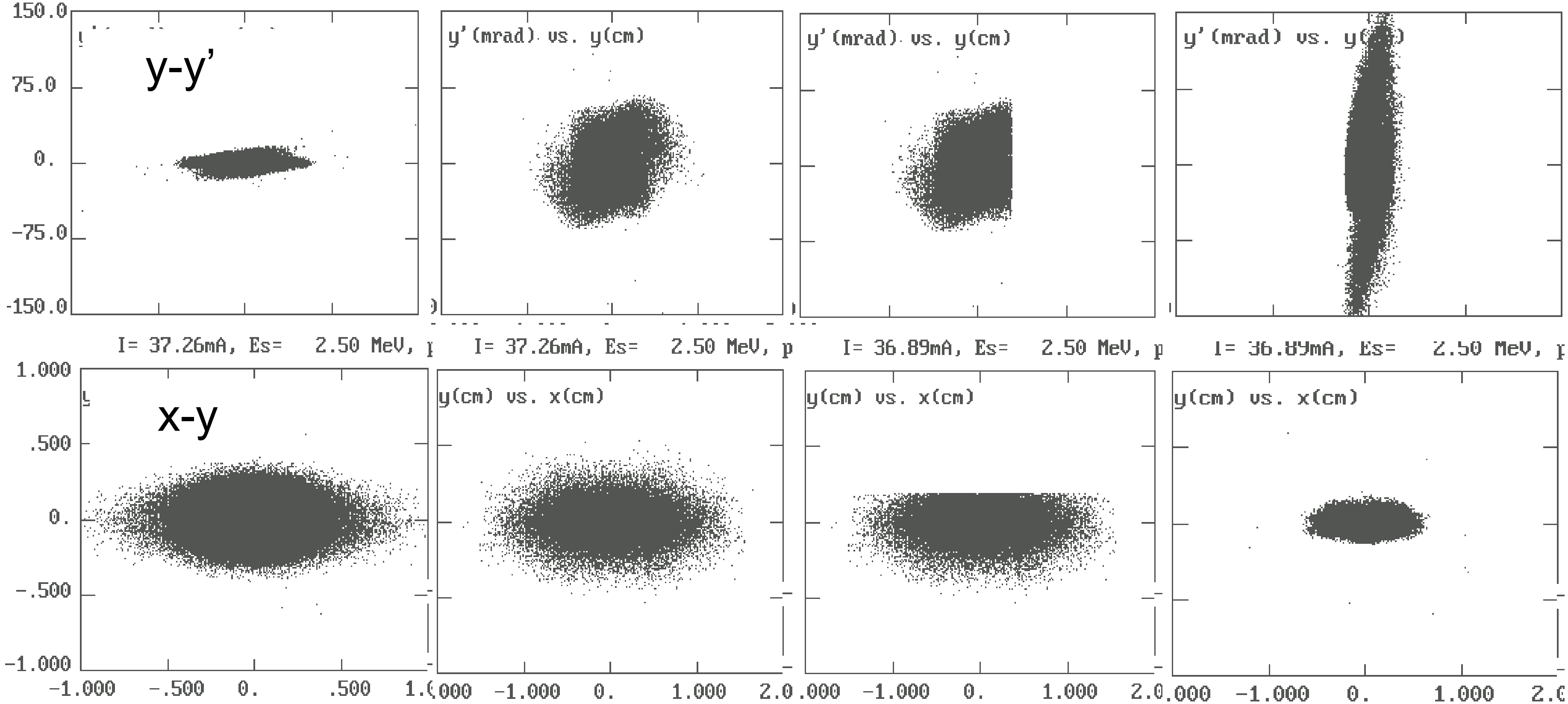
- There will be 5 partially chopped μbunches on each end of a minipulse
- Current ramping represents an additional 0.5%

Some Partially Chopped Beam May be Lost in the Linac

- Any fraction of 22 kW at risk is a concern
- Partially chopped beam from the LEBT/RFQ
  - May not be axial
  - May have large or distorted emittance
- Partially chopped beam from the MEBT
  - May not be axial
  - Will be mismatched to DTL
- Fully chopped beam from the MEBT
  - May not be fully chopped
- Turn-on ramp may be mismatched

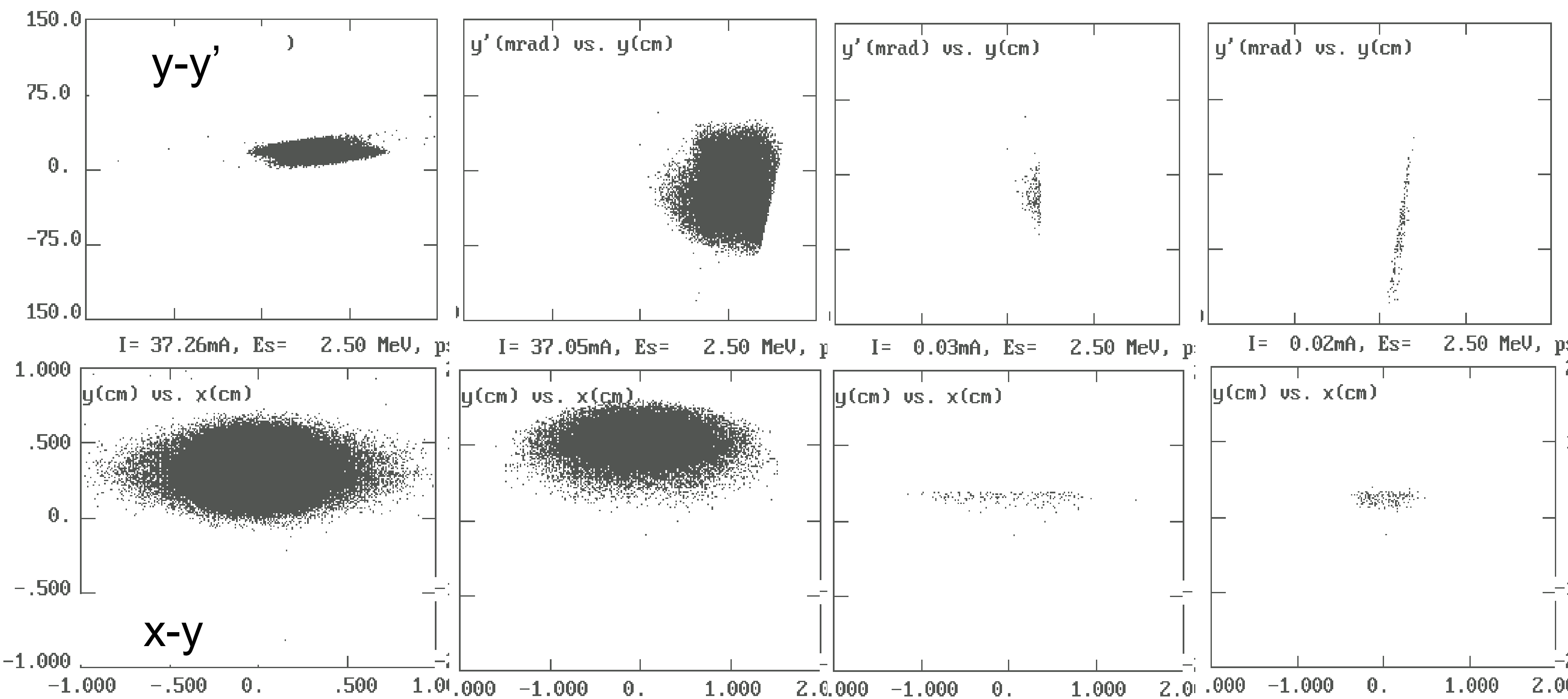
Chopper is Tuned to Remove 1% of the Unchopped Beam on the Target

chopper entrance | at chopper target | 1% removed on target | DTL entrance



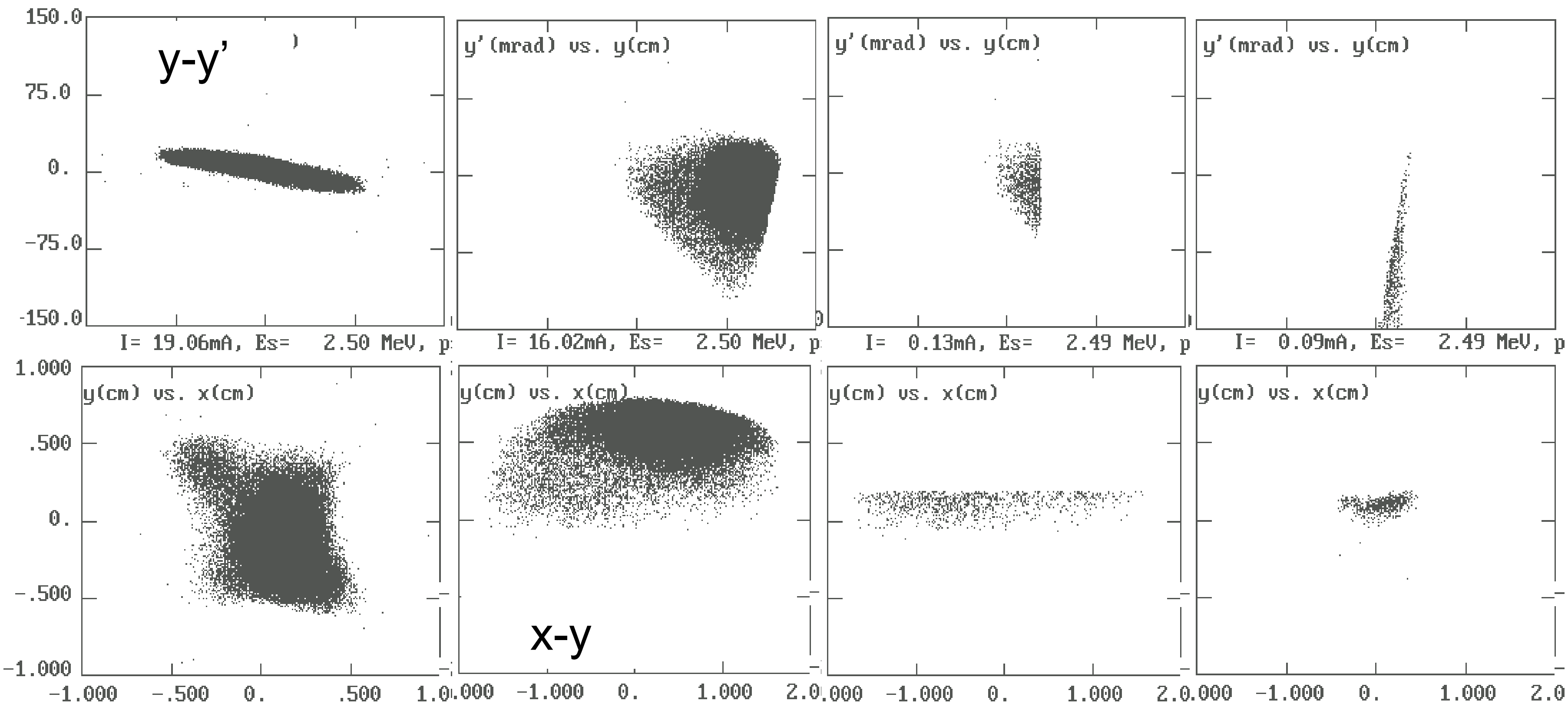
Without LEBT Chopping MEBT Chopper Leaves 5*10^-4 of the Beam in the Gap

end of chopper "plate" | at chopper target | < 0.1% survive target | 20 μA enter DTL



< 0.5% of a Half-Chopped Beam Survives the MEBT Chopper at Full Voltage

chopper entrance	at chopper target	0.7% survive target	90 μA enter DTL

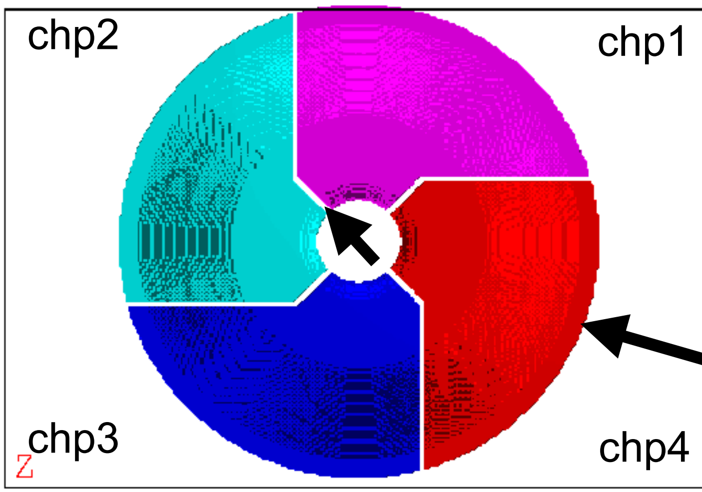


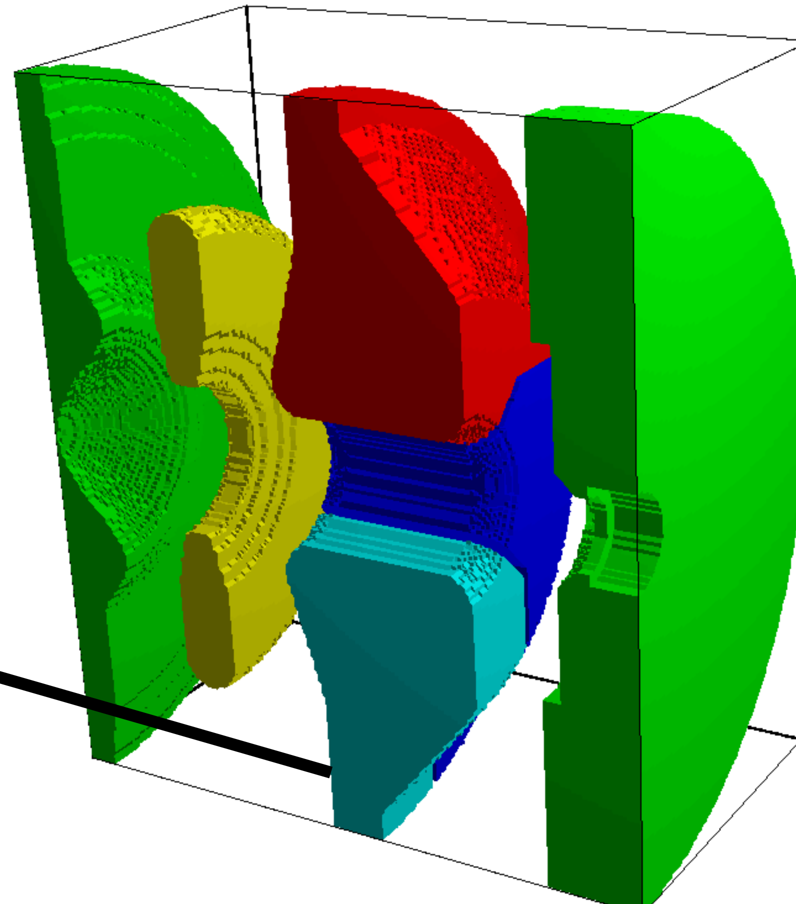
Chopper Studies are Proceeding

- Without LEBT chopping
  - MEBT chopper leaves ~20 μA in the gap
  - The requirement is $\leq$4 μA
  - With LEBT chopping this figure will certainly be met
- With partial LEBT chopping
  - MEBT beam is distorted and off-axis
- Initial simulations assume simple angular deflections in the LEBT chopper
- More detailed simulations will integrate particle dynamics through a 3-D field map of the LEBT Chopper
- Beam measurements are imminent

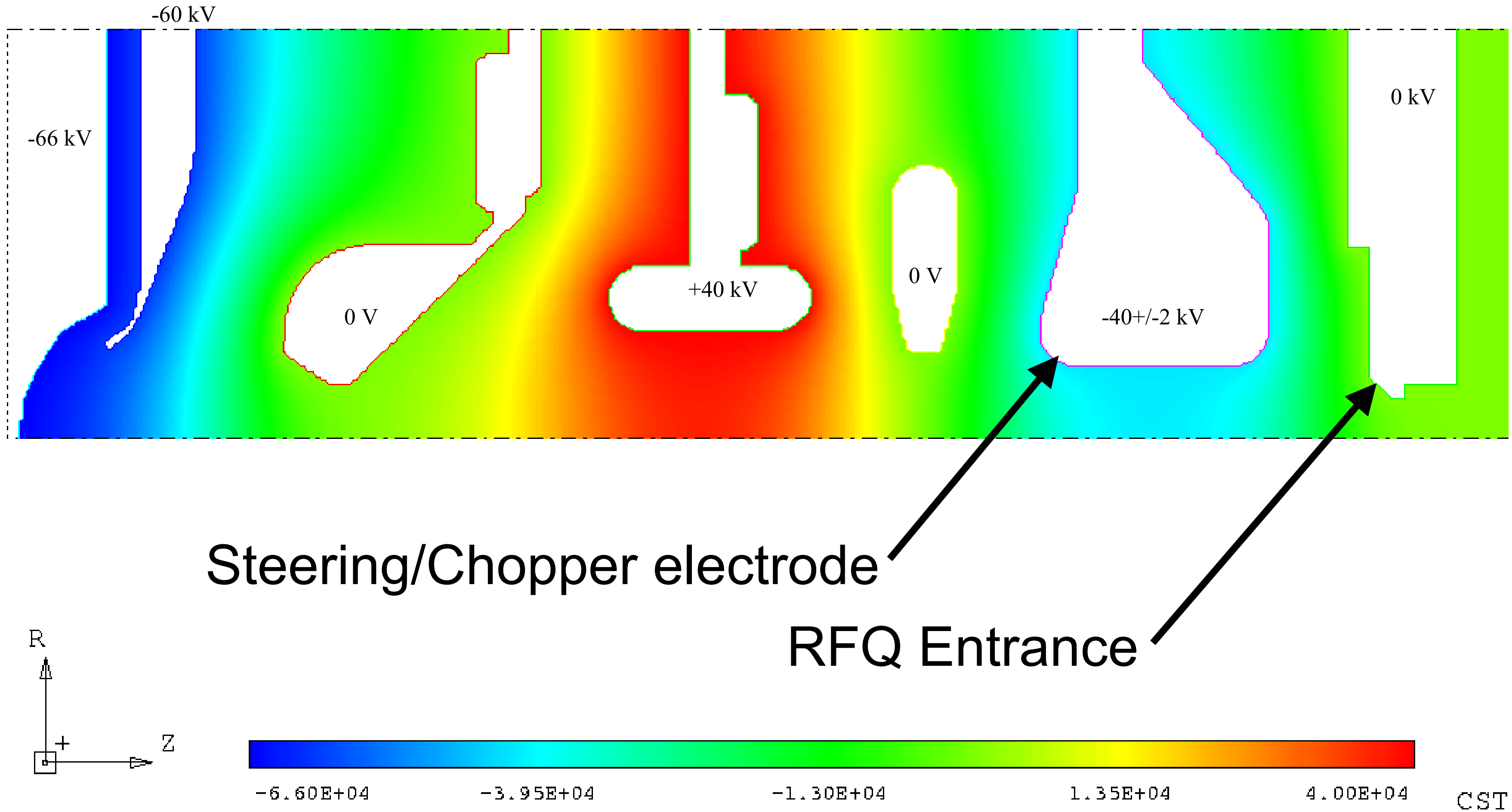
More Detailed Simulations will use a 3-D Field Map of the LEBT Chopper

Without chopping all electrodes = -40 kV
With chopping chp1 & chp2 = -38 kV
chp3 & chp4 = -42 kV





Without Steering or Chopping the LEBT has Axial Field Symmetry



Simulations using a “Measured” Beam Distribution Show ….

- The beam injected into the DTL has large tails
  - evolve into halo in DTL tank 1
  - halo is scraped at structure transitions in the linac
  - exceeds beam loss criteria of 1W/m
- Mismatch studies show that
  - any effect of modest mismatches is masked by the halo
- Chopping studies show that
  - The LEBT-MEBT chopper combination should effectively clean the gap
  - Destination of partially chopped beam awaits more detailed analysis

In the Next Episode we Plan to Show ….

- Implementation of halo mitigation strategy that will significantly reduce halo formation at its source
- Expected mismatches will not result in beam loss
  - Correlations between larger mismatches and beam degradation
- Chopping
  - The LEBT-MEBT chopper combination will completely clean the gap
  - There will be minimal beam loss at the chopping edges
  - Anti-chopper can be modified or eliminated to improve beam quality